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Input Filters For Receive Applications In The 144 MHz Range

Most active VHF amateurs will have noticed that many non-amateur signals are audible in the 2 m band. These can be caused by many things, and can also be generated in the receiver itself. For example, two or more legal out-of-band signals can generate in-band signals within the amateur band due to intermodulation in the input stage of the receiver or preamplifier. These can be mixed with the "wanted" signals and be demodulated with them.

A further problem can be caused by individual out-of-band signals from very strong transmitters that shift the operating point of the first stage and thus reduce the sensitivity of the receiver (desensitization). If the strong, out-of-band signal disappears, the (weak) amateur signal will be audible again. Such surprising variations are not caused by tropospheric propagation, but by the insufficient large-signal handling capability of our receiver.

Such interference can be reduced, or even completely suppressed by using a selective filter at the input of the receiver that only allows the required frequency range to pass.

A good filter will also reduce the sum power of ignition interference and other man-made noise (also a form of contamination!). Of course, the remaining interference in the band will still be bad enough, and one could assume that this problem could be solved by simply increasing the transmit power in order to ease reception. This may bring a temporary improvement, however, if all other transmitters operate with higher power, the same old situation will prevail. For this reason, attempts are being made throughout the world to improve the large-signal capabilities of receivers. The described bandpass filter represents one of these possibilities.

1. BANDPASS FILTER

As is probably known, the losses of a resonant circuit are dependent on the Q of the inductance L and the capacitance C. If the Q of a circuit is high, this will mean that the resonant curve is sharp. This curve can be made sharper – or its slope steeper – when two resonant circuits are coupled together. For quantitative calculations, which can be made with computers nowadays, one requires values of Q and degree of coupling. Calculations need not be made individually since the results can be taken from well-known tables and diagrams (1) and (2).

For the designing process, one requires the required frequency response with attenuation values at certain frequencies to form the basis of the calculation (**Figure 1**). The insertion loss (loss in the passband range) a_0 can fluctuate between a minimum and maximum value within the passband range (number of maximums corresponds to the number of coupled circuits). The corner frequencies of the passband range are to be designated f_{p1} and f_{p2}. The attenuation a_{c1} will appear at frequency f_{c1}, and the attenuation should obtain the value a_{c2} at f_{c2}.

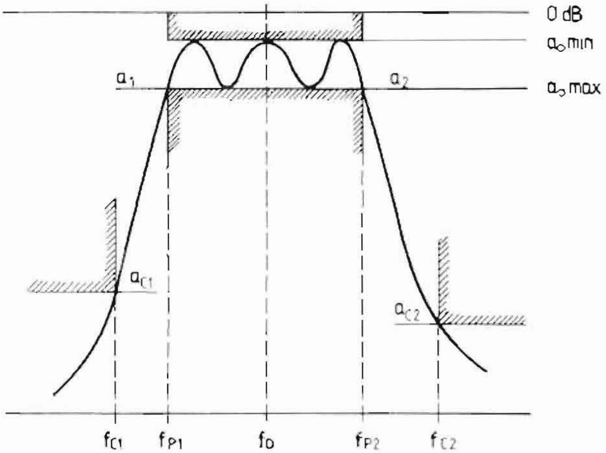

Fig. 1: Typical frequency response of a bandpass filter together with its specifications

The slope steepness of the filter is dependent on the number of resonant circuits and on the Q-values. The shape of the curve, that is its bandwidth, as well as the value of the insertion loss can be varied with the aid of the degree of coupling. If the coupling is fixed, the passband curve will become wider and the fluctuations of the attenuation (ripple) within the passband range will become greater. In the case of so-called critical coupling, the relationships are more favorable, but the bandwidth is lower. A loose coupling, finally, results in the lowest bandwidth, but also the highest insertion loss.

In other words, each filter design requires compromises and the task is to obtain a required bandwidth with a minimum of insertion loss, and at the same time to obtain the required attenuation values for out-of-band signals (ultimate attenuation).

2. 4-STAGE FILTER FOR 144 MHz

A filter is now to be described for home-construction whose specifications are given in Table 1:

Center frequency:	f_o = 145 MHz
Insertion loss:	a_o = 16–18 dB
Lower corner frequency	f_{p1} = 144 MHz
Attenuation at f_{p1}	a_1 = 2.0 dB
Upper corner frequency	f_{p2} = 146 MHz
Attenuation at f_{p2}	a_2 = 2.0 dB
Lower cut-off frequency	f_{c1} = 140 MHz
Attenuation at f_{c1}	a_{c1} = 36–40 dB
Upper cut-off frequency	f_{c2} = 150 MHz
Attenuation at f_{c2}	a_{c2} = 36–38 dB

Table 1: Filter specifications

The filter comprises capacitively coupled LC-circuits. In the case of 144 MHz, high-Q, air-spaced coils with compact dimensions can be used. When using silver-plated wire and not too many turns, one can obtain Q-values of over 100. This is, of course, no comparison to the Q of coaxial resonators (in the order of Q = 1000), but the manufacture is considerably simpler. Inductances for 144 MHz can be made from 1 mm dia. wire with a coil diameter of 6 to 8 mm.

Air-spaced or PTFE trimmers of 8 to 15 pF can be used for tuning, however, there are some other solutions. The construction of special coupling capacitors is also to be discussed in this article, since they contribute to the tuning elements.

Input and output are inductively coupled since they allow simple transformation from 50 Ω to the resonance impedance of the circuits which are usually in the order of kΩ. In order to achieve the required truely capacitive coupling, it is necessary for the individual inductances to be accommodated in screening chambers.

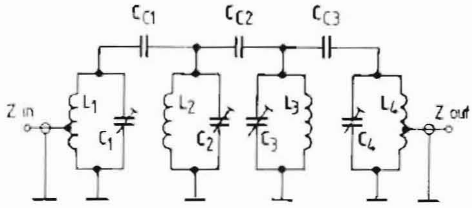

Fig. 2:
Equivalent circuit diagram of a 4-stage filter with capacitive coupling

3. CONSTRUCTION

The equivalent diagram of the 4-stage filter is shown in **Figure 2**. The wire length of the inductive taps amounts to 12 to 15 mm; they are connected to the coil at 0.25 to 0.75 turns from the cold end. Silver-plated copper wire of 1 mm diameter should be used, and this wound around a 6 mm former.

Special attention and care was paid to the construction of the coupling capacitors C_{c1} to C_{c3}. The idea was that two neighbouring conductive surfaces on a PC-board provided well-reproducible capacitance values in the required order of 0.2 to 1 pF. **Figure 3a** shows this arrangement and its equivalent circuit diagram. **Figure 3b** allows one to carry out one's own designs

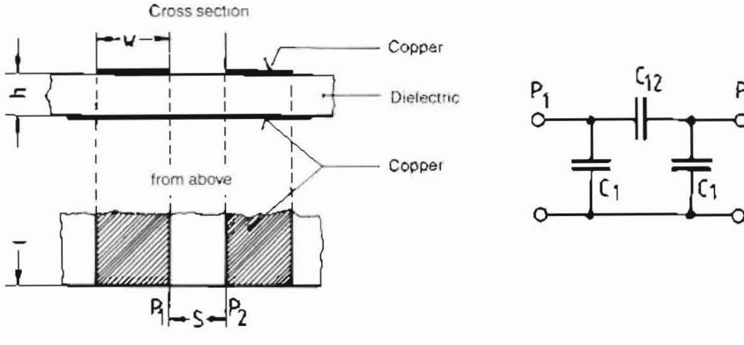

Fig. 3a: Schematic arrangement and equivalent circuit diagram of a coupling capacitor in stripline technology.

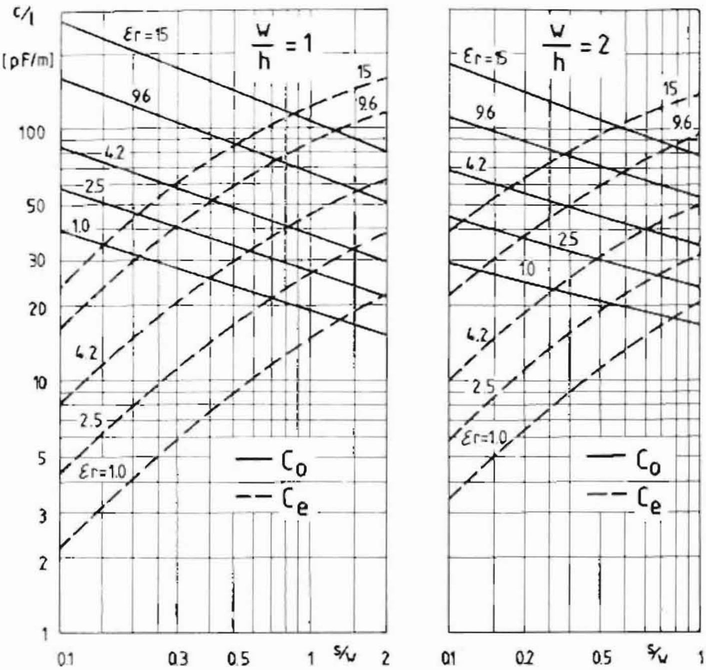

Fig. 3b: Design diagrams for stripline coupling capacitors

Our filter, comprising concentrated inductances and trimmers, is complemented by distributed capacitances using this easy-to-use and wide-spread stripline technology. These capacitances are realized on a double-coated PTFE-glass fibre PC-board with the dimensions 100 mm x 50 mm (**Figure 4**). The arrangement is symmetrical.

The inductances are constructed in a coaxial manner in chambers made from PC-board material as shown in **Figure 5**. All solder joints – also those of the two coaxial connectors (BNC) – must be on the inside so that completely RF-tight chambers without gaps result having a good electrical contact to the input and output connectors. It is only the coupling capacitors that conduct the RF-current from chamber to chamber. Tronser air-spaced trimmers are used that have four connections for which holes have been provided on the board.

3.1. Required Material

PC-board HA 5 KFV 001: 100 x 50 mm, constructed from double-coated glasfibre PTFE material (ε_r = 2.2), 1.5 mm thick (3M · 250 GX 15)

The following eight pieces are made from single-coated, normal PC-board material of 1.5 mm thickness:

3 pcs. intermediate panels, 47 x 25 mm
2 pcs. side pieces, 97 x 25 mm
2 pcs. panels with BNC connector, 50 x 25 mm
1 pc. cover 100 x 50 mm

Furthermore one will require:
2 BNC connectors (Radiall R-141554)
4 air-spaced trimmers
(Tronser 10-1111-20014-000)
4 air-spaced coils: 7 turns of 1 mm dia. silver-plated copper wire wound on a 6 mm former, self-supporting, connected between ground and the Tronser trimmer.

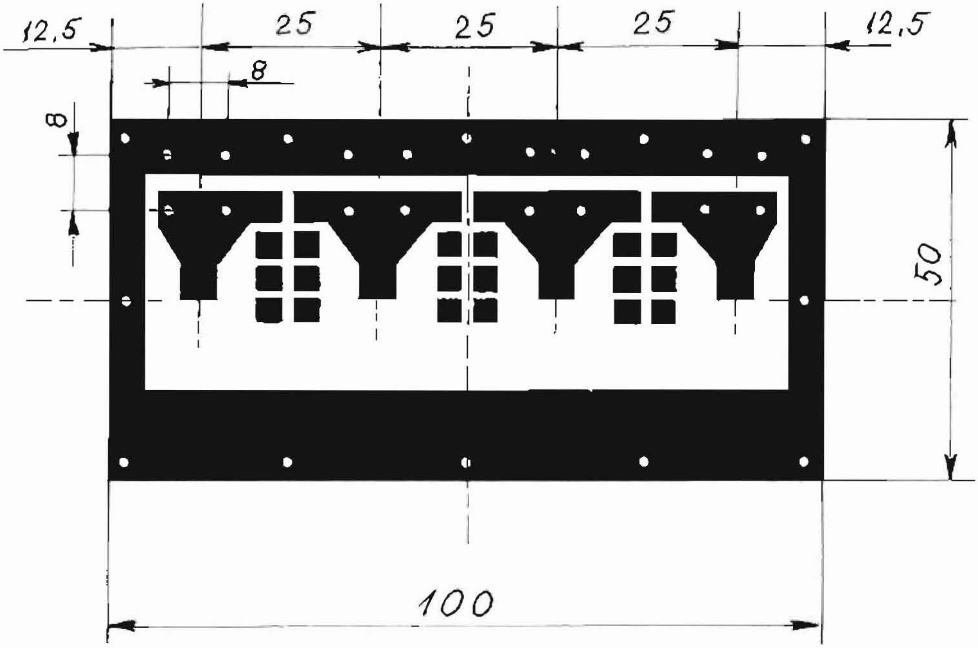

Fig. 4: PTFE PC-board HA 5 KFV 001 for a 4-stage bandpass filter for 144 MHz

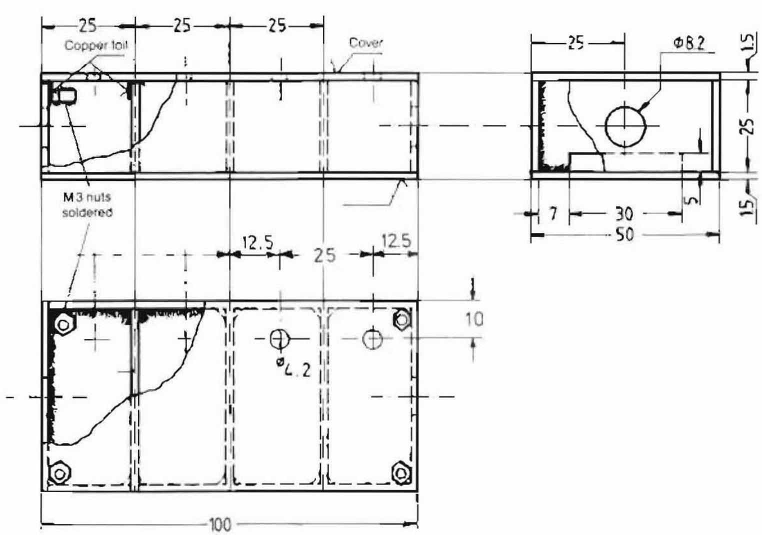

Fig. 5: Outside and intermediate panels, as well as the cover for the 4-stage filter
These can be made from single-coated PC-board material.

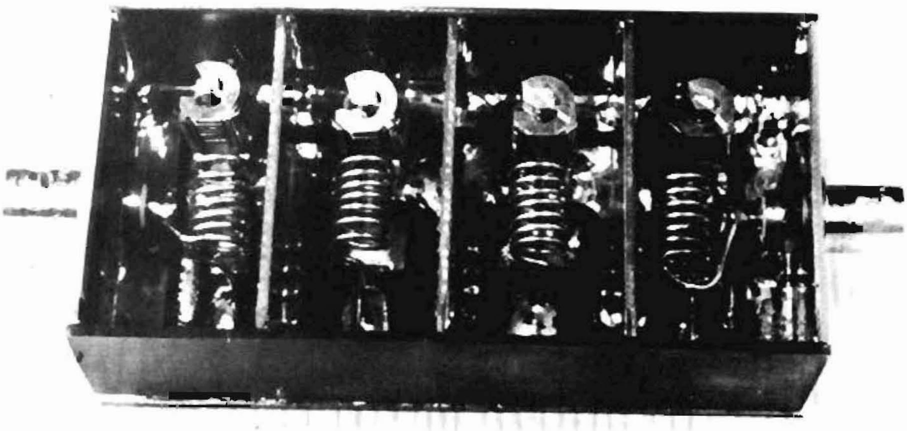

Fig. 6: Photograph of prototype filter, but without cover

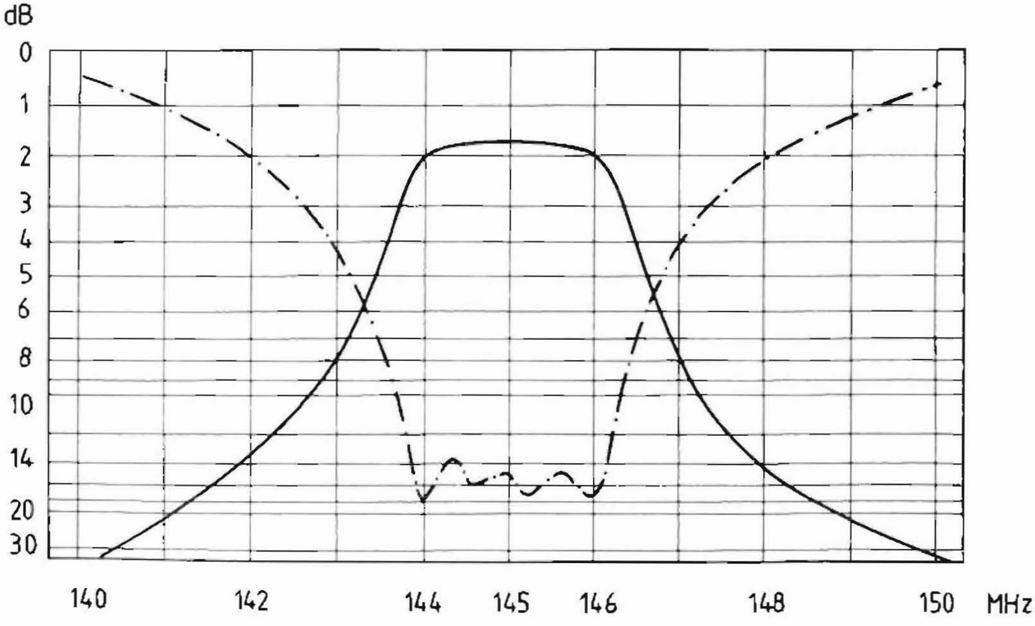

Fig. 7: Frequency response of attenuation (continuous line) and return loss of the input (dashed-dotted line)

Thin copper foil (approx. 0.1 mm thick) to solder the cover to the case and as metallic contact between cover and upper edge of the intermediate panels. A completed filter, but without cover, is given in **Figure 6**.

4. ALIGNMENT

Although one can exactly calculate all values, the manufacturing tolerances of the inductances, and the interaction of resonant circuit and coupling capacitances requires some form of alignment. For this reason, trimmers have been provided as well as several "capacitance islands" for the coupling. The less of these "capacitance islands" that are located opposite to each other, the looser will be the coupling. The optimum alignment of each 4-stage filter is a rather complicated process for which one requires a swept-frequency system or an RF network analyzer, and lots of patience.

The first step is to align all circuits to the center frequency of the band (145.0 MHz). The coupling is then improved in steps by soldering several islands together, until the required bandwidth is achieved. The input and output coupling should, on the other hand, be as loose as possible, what is achieved by connecting the tapping points as near to the cold end as possible. **Figure 7** shows the frequency response of amplitude and input matching after alignment.

5. REFERENCES

(1) D. G. Fink: Electronic Engineers Handbook, Mc-Graw Hill Publications, New York

(2) G. Pfitzenmaier: Tabellenbuch Tiefpasse SIEMENS AG, Munchen 1971